

## The Light Clock Experiments and the Law of Reflection

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Elementary classical physics tells us that when a ray of light strikes a plane mirror, the light ray reflects off the mirror. According to the law of reflection, the angle of incidence equals the angle of reflection.

One of the most important results of Special relativity (SR) is the effect of time dilation [1]. This phenomenon has been demonstrated in many experiments, including the muon experiment [2] and the experiment of synchronizing two atomic clocks [3].

Many physics textbooks deal with the subject of time dilation. This phenomenon can be depicted using a device known as a light clock [4]. In this note, it will be considered the relation between various light clock experiments and the law of reflection.

The light clock usually consists of two-plane parallel mirrors  $M_1$  and  $M_2$  that face each other and are separated by a proper distance  $d$ , Fig. 1a. A light signal (or photon) originating from mirror  $M_1$  is reflected by mirror  $M_2$  and finally returns to the location of mirror  $M_1$ , Fig. 1a. The light pulse traces out a path of length  $2d$ . Of course, the angles of light signal incidence and reflection are equal to zero.

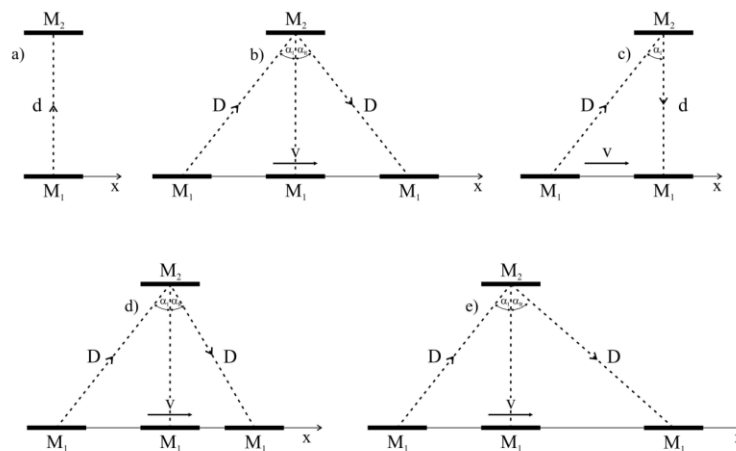


Fig. 1. Measurements and analysis for the light clock made in different frames. (a): No relative motion; (b) – (e): the light clock moving at speed  $v$ , see the text.

Now allow the same light clock to be moving with a certain relative speed  $v$  horizontally in the direction of the positive x-axis. In this case, a stationary observer who is watching the light clock could design the following diagram, Fig. 1b. As previously, the light signal of mirror  $M_1$  reaches

mirror  $M_2$  and reflects to mirror  $M_1$ . The light signal will now travel a larger distance  $2D$ . The stationary observer concludes that this signal again follows the law of reflection i. e., the angle of light signal incidence ( $\alpha_I$ ) is equal to its angle of reflection ( $\alpha_R$ ), Fig. 1b.

Let us assume that the light clock makes a full stop when the light signal reaches mirror  $M_2$ . The stationary observer determines that the light signal angle of incidence  $\alpha_I$  is greater than zero but its angle of reflection  $\alpha_R$  is zero degrees, Fig. 1c. Of course, this observation disagrees with the law of reflection. In addition, if we are dealing with a single photon as the light signal any process of its detection at the mirror  $M_2$  leads to its annihilation.

If the speed of the light clock after the light signal reaches mirror  $M_2$  is lower than  $v$  then the angle of reflection  $\alpha_R$  will be smaller than the angle of incidence  $\alpha_I$ , Fig. 1d. In the opposite case if this speed is higher than  $v$  the angle of incidence  $\alpha_I$  will be lower than the angle of reflection  $\alpha_R$ , Fig. 1e. Similar effects would be observed if the light signal after reaching mirror  $M_2$  travels at a speed lower (“slow light”) or higher (“fast light”) than  $c$ , for some reason.

All these observations also disagree with the law of reflection. My friends-physicists argue that this disagreement is a result of changing one inertial frame to another frame, though I am uneasy with this explanation. Indeed, SR states that “the speed  $c$  of light in a vacuum is the same in all inertial frames of reference in all directions and depends neither on the speed of the source nor on the speed of the observer” [Einstein, 1905]. It sounds rather strange that the direction of motion of light depends on the inertial frame.

## References

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